CLAIMS

1. A process comprising the hydroformylation of one or more olefins to form a hydroformylation product, wherein the hydroformylation takes place in a series of at least two hydroformylation reactors and wherein unreacted gases from hydroformylation or a subsequent process stage are recycled to at least the hydroformylation reactor in the second position.

2. The process according to claim 1 comprising a stage for hydrogenating the hydroformylation product to form alcohols, which process comprises catalytically hydroformylating the olefin(s), removing catalyst residues from the hydroformylation product to form a substantially catalyst-free hydroformylation product, and subsequently hydrogenating the substantially catalyst-free hydroformylation product, wherein the unreacted gases that are recycled comprise unreacted hydrogen from the hydrogenation stage.

3. The process according to claim 2 wherein the unreacted gases that are recycled comprise unreacted gases from the hydroformylation reaction and unreacted hydrogen from the hydrogenation stage.

4. The process according to any of the preceding claims wherein the hydroformylation is a high or medium pressure hydroformylation process in which the olefin(s) are reacted with carbon monoxide and hydrogen in the presence of a hydroformylation catalyst, wherein feed to the first reactor comprises a mixture of:

i. olefin(s)
ii. carbon monoxide
iii. hydrogen
iv. recycle gases comprising unreacted gaseous materials from the hydroformylation reaction;

and the feed to the reactor in the second position comprises a mixture of:

i.the reaction product from the first reactor
ii.recycle gases comprising unreacted gaseous materials from the hydroformylation reaction.

5. The process according to claim 4 in which the hydroformylation is performed in a series of at least three reactors and the feed to the reactor in the third position comprises:

i.the reaction product from the reactor in the second position
ii.recycle gases comprising gaseous materials from the hydroformylation reaction.

6. The process according to claim 4 or 5 in which the hydroformylation is performed in a series of four reactors and the feed to the reactor in the fourth position consists of the reaction product from the reactor in the third position.

7. The process according to any of the preceding claims in which the hydroformylation is performed at a pressure of from 50 to 350 barg, preferably 250 to 350 barg, most preferably from 275 to 325 barg.

8. The process according to any of the preceding claims in which the hydroformylation is performed at a temperature of from 120 to 185°C, preferably from 170 to 180°C.

9. The process according to any of the preceding claims employing a hydroformylation catalyst, in which the catalyst supplied is absorbed in the olefin feed.

10. The process according to any of the preceding claims employing a hydroformylation catalyst which comprises a rhodium catalyst or a cobalt catalyst, particularly those selected from hydrocobaltcarbonyl or rhodiumcarbonyls.

11. The process according to claim 10 in which the catalyst is a cobalt catalyst and the molar ratio of hydrogen to carbon monoxide in the syngas used for hydroformylation is about 1.3:1.

12. The process according to claim 10 or 11 in which the catalyst is a cobalt catalyst and the hydroformylation product is purified by injection of caustic soda and/or sodium carbonate into the hydroformylation reaction product in a decobalter vessel.

13. The process according to claim 12 in which a stoichiometric excess of 100 to 200%, particularly 140 to 180% of sodium hydroxide or carbonate is used.

14. The process according to claim 12 or 13 in which the decobalter is operated at a temperature in the range 155-165°C.

15. The process according to claim 10 or 11 in which the catalyst is a cobalt catalyst, and the cobalt is removed by an acidic and/or oxidative method.

16. The process according to claim 15 wherein the acidic method uses formic and/or acetic acid.

17. The process according to claim 15 or 16 wherein the oxidative method uses oxygen, an oxygen containing gas, or air.

18. The process according to any of the preceding claims in which the hydroformylation product is fed to a high pressure separator where free gas is separated from the liquid phase as high pressure offgas.

19. The process according to claim 18 in which the high pressure separator operates at a pressure of 250 barg or higher, preferably a pressure in the range 250 to 300 barg, more preferably 260 to 270 barg.

20. The process according to claim 18 or 19 in which the quantity of high pressure gas required for recycle is sent to an offgas recycle compressor system.

21. The process according to any of claims 18 to 20 in which the liquid left in the high pressure separator is fed to an intermediate pressure separator where the pressure is reduced to a level at which gases dissolved or entrained in the liquid from the high pressure separator are released as an intermediate pressure offgas.

22. The process according to claim 21 in which the pressure in the intermediate pressure separator is between 80 and 120 barg, preferably between 90 and 110 barg.

23. The process according to claim 21 or 22 in which at least a portion of the intermediate pressure offgas is sent to an offgas recycle compressor system for subsequent recycle.

24. The process according to any of the preceding claims in which the recycle employs a compressor system comprising a series of gas compressor stages in which the pressure is gradually increased to the pressure required in the hydroformylation reaction.

25. The process according to claim 24 in which the recycle compressor system comprises three gas compressor stages in series.

26. The process according to claim 25 in which high pressure offgas and intermediate pressure offgas from the hydroformylation step are fed (together

with unreacted gas from the hydrogenation stage, when present) to the first compressor stage which preferably operates at a suction pressure between 50 and 60 barg.

27. The process according to claim 26 in which the gas mixture discharged from the first compressor stage is fed, optionally with intermediate pressure offgas, to the second compressor stage where the pressure is increased to within the range 140 to 180 barg, preferably 150 to 170 barg.

28. The process according to claim 27 in which the gas mixture discharged from the second compressor stage is fed, optionally with high pressure offgas, to the third compressor stage.

29. The process according to any of the preceding claims wherein duplex stainless steel is used as material of construction for at least one piece of the hydroformylation reactors or any of their associated equipment.

30. An apparatus for the production of alcohols from an olefin, comprising a series of at least two reactors for catalytic hydroformylation of olefin, means for the removal of catalyst residues from the hydroformylation product, a reactor for hydrogenating the hydroformylation product from which catalyst residues have been removed, and means whereby unreacted hydrogen from the hydrogenation reactor is recycled to at least the second hydroformylation reactor.

31. An apparatus for the production of alcohols from an olefin, comprising a series of at least two reactors for catalytic hydroformylation of olefin, means for the removal of catalyst residues from the hydroformylation product, a reactor for hydrogenating the hydroformylation product from which catalyst residues have been removed, and means to recycle unreacted gases from the hydroformylation reaction to at least the second hydroformylation reactor.

32. The apparatus according to claim 30 and 31 which comprises both means for recycling unreacted hydrogen from the hydrogenation reactor, and means for recycling unreacted gases from the hydroformylation reaction.

33. The apparatus according to claim 30, 31 or 32 wherein duplex stainless steel is used as material of construction for at least one piece of the hydroformylation reactors or any of their associated equipment.